Special Report 80-11

March 1980

12

LEVEL II

AD A084276

SNOW FORTIFICATIONS AS PROTECTION AGAINST SHAPED CHARGE ANTITANK PROJECTILES

Dennis Farrell

Prepared for
DIRECTORATE OF MILITARY PROGRAMS
OFFICE, CHIEF OF ENGINEERS
By
UNITED STATES ARMY
CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE, U.S.A.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 9 Special Rep[redacted]t 80-11
2. GOVT ACCESSION NO.: AD-A084 276
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): 6 SNOW FORTIFICATIONS AS PROTECTION AGAINST SHAPED CHARGE ANTITANK PROJECTILES.
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): 10 Dennis Farrell
8. CONTRACT OR GRANT NUMBER(s): 16
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA Project 4A762730AT42, Task A, Work Unit 001
11. CONTROLLING OFFICE NAME AND ADDRESS: 11 Directorate of Military Programs, Office, Chief of Engineers, Washington, D.C. 20314
12. REPORT DATE: Mar[redacted]80
13. NUMBER OF PAGES: 22
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 24
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): 14 CRREL-SR-80-11
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Cold weather operations
Snow
Construction materials
Fortifications
Recoilless guns
Shaped charge jets

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report chronicles an investigation of the effectiveness of snow fortifications.

The test was planned to observe and measure how packed snow adsorbs the energy of high explosive antitank (HEAT) ammunition. In the test plan we considered both the possibility of non-detonation due to insufficient resistance in snow and the rate of deterioration of a snow embankment with repeated impacts. The 90-mm M67 recoilless rifle was used because it has a relatively

cont'd

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

037100

20. Abstract (cont.)

low velocity and its charge was more likely to not detonate than that of a high velocity weapon. The charge weight and configuration were similar to other ammunition of this caliber. We found that (1) 29 of 30 live rounds detonated on impact; (2) damage to inert rounds which were retrieved from the embankment ranged from slight to negligible; (3) maximum penetration of the shaped charge was less than 3.5 m; maximum penetration of the inert rounds was less than 3.0 m; and (4) a packed snow embankment does not deteriorate rapidly under sustained fire. These findings indicate that snow can be used to good advantage for building expedient fortifications, particularly in situations where large volumes of snow have to be cleared from roads and airfields.

PREFACE

This report was prepared by Dennis R. Farrell, Mechanical Engineer, Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

The study was funded under DA Project 4A762730AT42, Design, Construction and Operations Technology for Cold Regions; Task A1, Ice and Snow Technology; Work Unit 001, Terminal Ballistics in Snow, Ice and Frozen Soil.

The author expresses appreciation to Mr. George Aitken and Dr. George Swinzow for their comments on the test procedures and review of this report and to LTC Getman for giving us the opportunity to observe the operations of the air-to-ground practice ranges at Ft. Drum, N.Y.

Contents

INTRODUCTION

The work described in this report was conducted as part of an investigation by the U.S. Army Cold Regions Research and Engineering Laboratory into the terminal ballistics of various projectiles in snow, ice and frozen soil. The report describes the results of tests conducted at Ft. Drum, N.Y., in which HEAT (high explosive antitank) and inert rounds were fired from a 90-mm recoilless rifle (Fig. 1, 2) at snow embankments.

A review of Army publications on northern operations indicated that rapid construction of defensive positions in a winter environment requires special techniques. Several of the Army Field Manuals provide information about construction of defensive positions using materials other than soil when the frost layer is too thick for rapid manual excavation. At least four of the manuals have tables that give the quantity of snow required to stop bullets from small arms. These manuals are:

1) FM 5-15, Field Fortifications
2) FM 31-70, Basic Cold Weather Manual
3) FM 31-71, Northern Operations
4) TM 5-349, Arctic Construction

The work described in this report was conducted to determine if snow in reasonable quantities could also be used to protect stationary vehicles, parked aircraft, and fixed facilities against the larger armor-piercing infantry weapons. The objectives of the tests were 1) to determine the problems associated with collecting large volumes of snow under field conditions, 2) to observe the functioning of a typical piezoelectric fuze when it strikes packed snow, and 3) to measure the ability of snow to absorb the focused explosive force of a shaped-charge antitank round.

TARGET CONSTRUCTION

A 6-m-thick, 2 1/2-m-high, 40-m-long snow embankment was constructed using a D-6 tractor and a 2-yd^3 capacity front end loader. Because the two vehicles worked in tandem collecting and piling the snow, production rates are not available for each piece of equipment separately. The overall production rate was 48 m^3/hr.

Johnson (1977)* reported that two men with large scoops produced a 14-m^3 snowpile from undisturbed snow at the rate of 11.2 m^3/hr. This rate compares favorably with that of the heavy equipment (see Table 1), but natural conditions and test requirements (particularly the requirement for minimal contamination by soil) reduced the production rate of the heavy equipment by at least a factor of two. It is suggested that the figure of 48 m^3/hr for the two machines should be viewed as the lower limit for the production rate of this type of equipment under these conditions.

*Johnson, P. (1977) Defensive Works of Subarctic Snow. CRREL Report 77-6, April.

Table 1. Comparison of hand- and machine-built snow embankments.

Type of construction	Density Initial (Mg/m^3)	Density Final (Mg/m^3)	Initial snow depth (cm)	Embankment volume (m^3)	Rate of const. (m^3/hr)
Hand	0.18	0.34	66	14.0	11.2
Machine	0.24	0.44	47	600	48

TEST EQUIPMENT AND PROCEDURE

Aberdeen Proving Ground, Maryland, provided 30 rounds of 90-mm HEAT M371E ammunition, 20 inert rounds, and an M67 90-mm recoilless rifle (Fig. 1,2). Six live HEAT rounds and five inert rounds were fired at the embankment. The trajectories in the snow were excavated gradually from the side after each shot until all the effects of the impact were exposed and measured (Fig. 3,4). The observations and recorded measurements are given in Table 2. Two additional HEAT rounds were fired at specially prepared vertical surfaces on the berm to provide more symmetrically shaped craters for more accurate crater dimension measurements.

The remaining 22 HEAT rounds were all fired into a 2-m-wide section of the berm to observe the deterioration of the berm under repeated impacts. The test was filmed and some general observations were made, but mechanical failure of the excavating equipment prevented a detailed inspection of the results.

In addition five inert rounds were fired at separate impact points on the snow embankment. The trajectories were excavated and the projectiles were recovered. Depth of penetration was recorded (Table 2) and the damage to the projectile was observed, particularly on the nose where the piezoelectric sensor is located.

Three more inert rounds were fired at shallow angles into undisturbed snow to determine if a fin-stabilized projectile with this unusual nose shape would show the same tendency to broach or ricochet that many ogive-shaped, spin-stabilized projectiles had exhibited in previous tests (Johnson 1977, op. cit.).

An unexpected opportunity to observe the terminal effects of other military projectiles presented itself when we were invited to watch training exercises at the Air National Guard's air-to-ground gunnery range at Ft. Drum. Both our group and the Air Force personnel were quite surprised by the observations we made following practice bombing and strafing into an undisturbed snow cover (see Appendix).

TEST RESULTS

Of the 30 live HEAT rounds fired at the snow embankment from a distance of 150 m, 29 detonated in the packed snow. One detonation failure

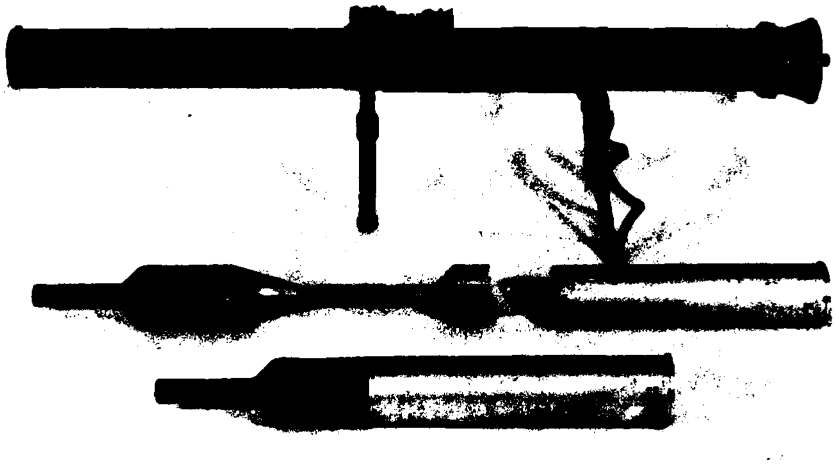


Figure 1. M67 recoilless rifle and M371E1 HEAT (high explosive antitank) ammunition.

Figure 2. Loading the recoilless rifle.

Figure 3. Excavating the snow berm with a D-6 tractor.

Figure 4. Shaped charge jet trajectory exposed by excavation (arrows).

Table 2. Measurements of shaped charge and inert round penetration.

Penetration (m)	Entrance cavity length (m)	Crater depth (m)	Crater radius (m)	Remarks
Shaped charge HEAT rounds				
3.1	0.5	0.4	0.8	Air temp -4°C, snow density 0.32 Mg/m^3, front, 0.44 Mg/m^3 center, 0.59 Mg/m^3 rear.
1.5	-	-	-	Impacted frozen soil in snow.
3.4	0.5	0.7	0.9	
2.9	-	0.8	0.9	Snow density 0.40 Mg/m^3, 0.34 Mg/m^3, 0.44 Mg/m^3, 0.41 Mg/m^3, 0.42 Mg/m^3 rear.
3.0	-	0.9	0.8	Jet barely exited rear of berm.
3.0	-	1.0	0.7	Snow density 0.47 Mg/m^3 front, 0.48 Mg/m^3 center, 0.50 Mg/m^3 rear.
-	-	0.8	0.9	
-	-	0.8	0.7	
Inert rounds				
2.4	N/A	N/A	N/A	Air temp -4°C
2.8				
2.0 (Flew 20 m after exit)				Hit shallow section of berm and exited rear.
2.0				
1.5 (Flew 15 m after exit)				Hit shallow section of berm and exited rear.

occurred during the multi-impact phase of the testing. The round impacted high on the berm, penetrated about 1 m of snow and continued down range. The cause of detonation failure could not be determined.

Figure 4 illustrates a typical cross section of an impact area, showing the 2 to 3-cm-wide column of copper and explosive residue from the shaped charge jet. As shown in Table 2, the maximum depth of penetration of the shaped charge jet of the HEAT rounds was about 3.0 m

in almost all cases. The approximate crater dimensions given in Table 2 show that nearly 2.0 m^3 of snow was compacted or expelled by each impact. Figure 5 shows a typical inert round trajectory after the snow was excavated. Because the inert rounds were fired into a smaller section of the berm, two of the five rounds completely penetrated the berm and continued down-range 15 to 20 m (Fig. 6). As shown in Table 2, none of the inert rounds penetrated more than 3 m of packed snow. These tests demonstrated the capacity of snow to absorb both the high velocity, low mass products of an explosive charge and a relatively low velocity, high mass inert round.

The multiple impact test was conducted on a 2-m-wide, 6-m-deep, 2 1/2-m-high section of the berm. Eight rounds were required to make a notch through the top of the berm. Although the repeated impacts must have caused some disaggregation of the snow, it required all 22 rounds to reduce a 2-m-wide section of the berm to half its original height.

Observations of physical damage to the inert projectiles were used to analyze roughly the forces and projectile decelerations generated by impact. Figure 7 shows the nose sections of three recovered inert projectiles. As typified by the projectile on the left, three of the five inert projectiles exhibited no signs of plastic deformation and only slight abrasion of paint on the aluminum nose cap. In a live shell, a piezoelectric sensor inside the nose cap activates the fuze when it is strained (Fig. 8)*. As indicated by the absence of deformation to the projectile at the left in Figure 7, impact in packed snow did not apply a significant amount of pressure on the actuator. However, the sensor is so sensitive that 29 of 30 rounds detonated. In addition, only two of the five rounds recovered showed evidence of impact with soil or other contaminants in the snow. This observation suggests that the packed snow was detonating the live rounds.

Table 3 presents the data obtained from three inert projectiles fired at low angles into undisturbed snow. All three projectiles broached and impacted again 200-400 m down range. Measurements of the trenches formed in the snow show the projectiles penetrated to a maximum depth of less than 30 cm in the 66-cm snow cover before they broached.

CONCLUSIONS

Based on the analysis of the data from these tests, the following conclusions can be made.

1. Conservatively, three and a half meters of well-packed snow is sufficient to absorb both the high velocity, concentrated explosive products of HEAT rounds and the low velocity and high mass of inert rounds fired from a 90-mm recoilless rifle.

---

* HQ USAMC (1976) Engineering design handbook, recoilless weapon systems. AMC Pamphlet 706-238.

Figure 5. Excavated inert round trajectory.

Figure 6. An inert round that penetrated the berm.

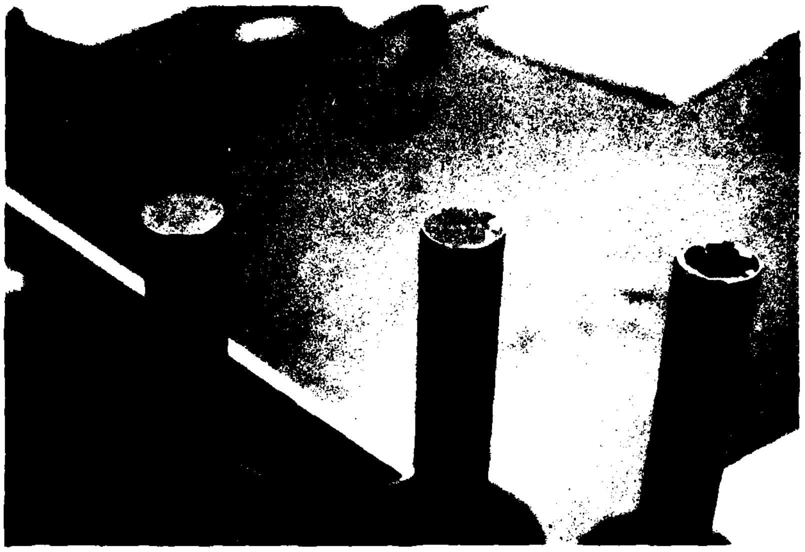


Figure 7. Nose caps of three 90-mm inert rounds recovered from snow berm.

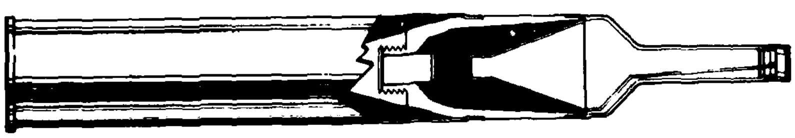
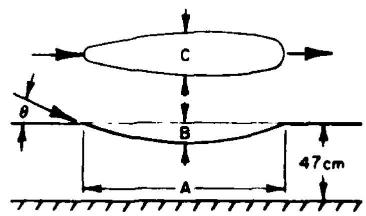


Figure 8. 90-mm HEAT cartridge M371E1.

Table 3. Dimensions of trenches excavated by 90-mm inert rounds impacting at low angles and broaching.



Shot	Impact angle (θ) (mils)(degrees)	A (cm)	B (cm)	C (cm)
1	30 (1.7°)	287	20.3	33.0
2	40 (2.2°)	345	28.0	61.0
3	120 (6.7°)	353	25.4	48.3

2. A snow embankment offers enough resistance to detonate HEAT rounds even with the relatively low muzzle velocity (213 m/s) of the M67 recoilless rifle.

3. A multiple impact test series with 22 HEAT rounds showed that sustained fire results in a suprisingly gradual collapse of a snow embankment. The snow embankment was only notched to half its original height by the combined impacts. This observation suggests that the energy-absorbing properties of snow were not degraded (and perhaps possibly were enhanced) by repeated impacts.

RECOMMENDATIONS

A more comprehensive understanding of techniques for employing snow as a fortification material can offer potential advantages to military engineers operating in cold regions. Every winter, military engineers in many parts of the world must move tons of snow. With some basic planning and little additional effort, this snow could be used to protect parked aircraft, to build roadside fortifications, and to aid our combat forces in a variety of other ways.

APPENDIX

On 10 January 1976, a short delay in the CRREL testing schedule permitted close observation of the Air National Guard's air-to-ground gunnery range.

The range actually consists of three separate ranges:

1. A bomb circle 58 m (175 ft) in diameter for practice exercises using jet fighter and close support aircraft armed with practice bombs that emit a charge of smoke on impact.

2. A target 3 m (10 ft) in diameter marked by a suspended drag chute with electronic sensors to record hits by jet aircraft strafing with 7.62-mm ball ammunition.

3. A similar strafing range for aircraft armed with 20-mm inert ammunition.

In previous years the range had been closed during the winter months. This first season of winter operation presented many problems for the Air Force personnel, some of which parallel difficulties that could be encountered on a winter battlefield.

The month of January began with several days of heavy snow at near freezing temperatures followed by a few days of clear weather. Then -10° to -25°C air temperatures with moderate winds and occasional snow squalls left a smooth surface of undisturbed snow on the range. The result was a layer of snow 44 cm deep with a density of 0.22 to 0.26 Mg/m^3 covered by a 1-cm-thick crust created by the sudden drop in air temperature and compaction by the wind. There were 2 cm of light snow with an approximate density of 0.10 to 0.15 Mg/m^3 on top of the crust. The undisturbed snow provided excellent evidence of the effects of bombardment when the first flight used the range after the weather cleared.

The soil beneath the snow had minimal frost penetration because the heavy snow accumulation provided insulation during the few days of low air temperatures. The soil in the vicinity of the strafing targets was not affected because it had been covered by at least a foot of gravel during the previous summer. The soil in the bomb circle appeared to be a saturated silty clay. The Air Force personnel described the area as a virtual bog in the summer. The bomb circle was heavily cratered by live rocket fire. Some of the craters were almost 1 m deep and were filled with drifting snow at the time of the exercise.

The three F-100 fighters that used the range were each armed with six practice bombs and 100-130 rounds of 20-mm inert ammunition for strafing practice. The bombs were dropped from various heights, resulting in impact angles from 45 to 60 degrees. The attack angles on the strafing range varied between 10 and 30 degrees.

On the bombing range, the range crew was having difficulty seeing the smoke from the spotting charges that were supposed to mark the impact points of the bombs. Approximately 15% of the bomb impacts were not detected and were designated "no-spots" in the records. This problem began after the first heavy snowfall.

On the day of the exercises, flying conditions were ideal, with an air temperature of 0 to -10°C. The schedule for the three F-100's began with bombing practice. As in previous exercises, three of the eighteen drops could not be spotted and some were spotted only after a delay of several seconds. Figures A1-A3 show three different types of post-impact bomb behavior. Figure A1 illustrates a normal crater. This impact was spotted from the observation and control towers. Figure A2 shows an entrance crater and a shear zone on the snow surface extending several meters from the impact point. Dissection of the snow along the trajectory revealed that the bomb had been deflected by the snow, glanced off the soil, and detonated when it struck a high spot in the soil beneath the snow, about 3 m from its impact point. Figure A3 shows the trajectory of a bomb that broached from the snow after impact. It apparently detonated about 25 m down range at the point indicated by the arrow. The craters in Figures A2 and A3 were found outside the bomb circle. The bombs in Figures A2 and A3 probably had a low impact angle, but past records indicated a higher incidence of "no-spots" at high impact angles. From observations, it appeared that some of the practice bombs fell into the craters filled with deep snow within the bomb circle and either failed to detonate or had their detonation smothered by the snow.

In Figure A4 it is hypothesized that at a high impact angle the bombs sank deep into the crater before making solid contact with the soil. At the lower angles the bombs are more apt to strike the crater wall at a nearly perpendicular angle, penetrating less snow before striking the soil. The low angle bombs were less likely to have visible smoke charges since the tails of the bombs were engulfed by snow. From these observations we assumed that the more even ground outside the bomb circle encouraged "no-spots" at low impact angles and the cratered terrain of the bomb circle encouraged "no-spots" at high impact angles.

In an effort to correct this problem within the bomb circle, the area was backgraded with a bulldozer. Some of the unfrozen soil was pushed into the craters on top of the snow. This procedure significantly reduced the frequency of the "no-spots." The surface snow was compacted, reducing its insulating value. An accelerated freezing rate in the soil was observed during the inspection of bomb craters from later air strikes. The packed snow had also hardened to the point that it would easily support the weight of a man, but it could not be determined if any detonations had occurred on the packed snow surface. A brief survey after subsequent exercises revealed that most, if not all, of the spotting charge failures were now occurring outside the bomb circle in the unpacked snow.

Figure A1. A typical bomb crater with good detonation of the spotting charge.

Figure A2. Apparent low angle impact in undisturbed snow.

Figure A3. Apparent low angle impact resulting in broaching and detonation on second impact (arrow).

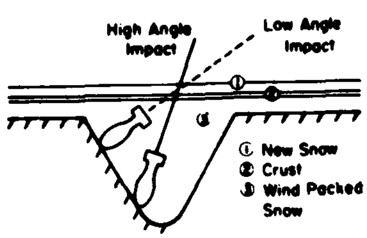


Figure A4. Hypothetical bomb impacts in the heavily cratered bomb circle showing relationship between angle of impact and depth of penetration below snow surface.

On the strafing range the only problem had been some fouling of the target sensors by drifting snow, but the range crew had also noticed numerous spent rounds scattered over the surface of the snow in the vicinity of both the 20-mm and 7.62-mm targets following previous exercises. Many of these rounds showed little or no surface abrasion except for the marks of the rifling. The test crew recalled that during the summer exercises the projectiles had been severely damaged on impact and that it had been unusual to find more than half of a projectile still intact.

The two rounds shown in Figure A5 were retrieved from the snow. The round on the left was found in the immediate vicinity of the target while the round to the right in the photo was found about 100 m down range from the target. The projectile found near the target shows some abrasion of the painted surface while the projectile recovered down range had negligible abrasion. In fact, there is so little physical damage to this projectile that there is a question as to whether or not a live round of this type would be detonated by the impact.

Figure A6 illustrates the ability of snow to alter the normal flight of a projectile; it shows two typical patterns that the 20-mm projectiles caused in the snow. The pattern in Figure A6a is typical for the round that was abraded. This pattern was observed in approximately three-quarters of the impacts. It appeared that the rounds passed through the snow cover and glanced off the soil, which caused the abrasion, then tumbled through the snow, coming to rest between 70 and 120 cm from the point of impact.

The pattern of a round that continued down range after broaching is shown in Figure A6b. Note that the projectile veered to the right because of its right hand spin. This deflection was observed not only in the initial pattern but also in subsequent patterns because many of the projectiles skipped several times as they continued down range. The hard crust 2 cm beneath the top of the snow appeared to encourage broaching as the velocity of the projectiles decayed down range, but on initial impact the round seemed to pass easily down through the crust layer and then pass up through the crust layer just as easily. This is indicated by the depth of the snow trenches of the initial impacts.

Figure A7b shows a round that broached and came to rest only about 50 m from the target.

Figure A8 illustrates the pattern caused by a round when it finally stopped on a hillside about 150 m from the target (indicated by the arrow in Fig. A8a) and some 30 degrees to the right of its original trajectory. Notice that in Figure A8b the trajectory, instead of veering to the right (as viewed from the target), abruptly veers to the left. The snow was brushed aside before the close-up (Fig. A8c) was taken. It reveals that the round rolled sideways for the last 2 m. The obvious implication is that the forward momentum had decayed, but that the round was still spinning, causing it to roll the last 2 m before it stopped.

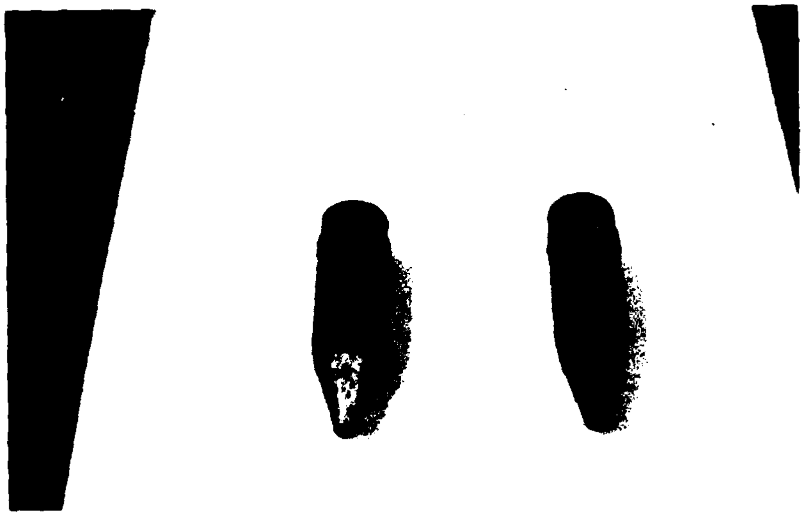
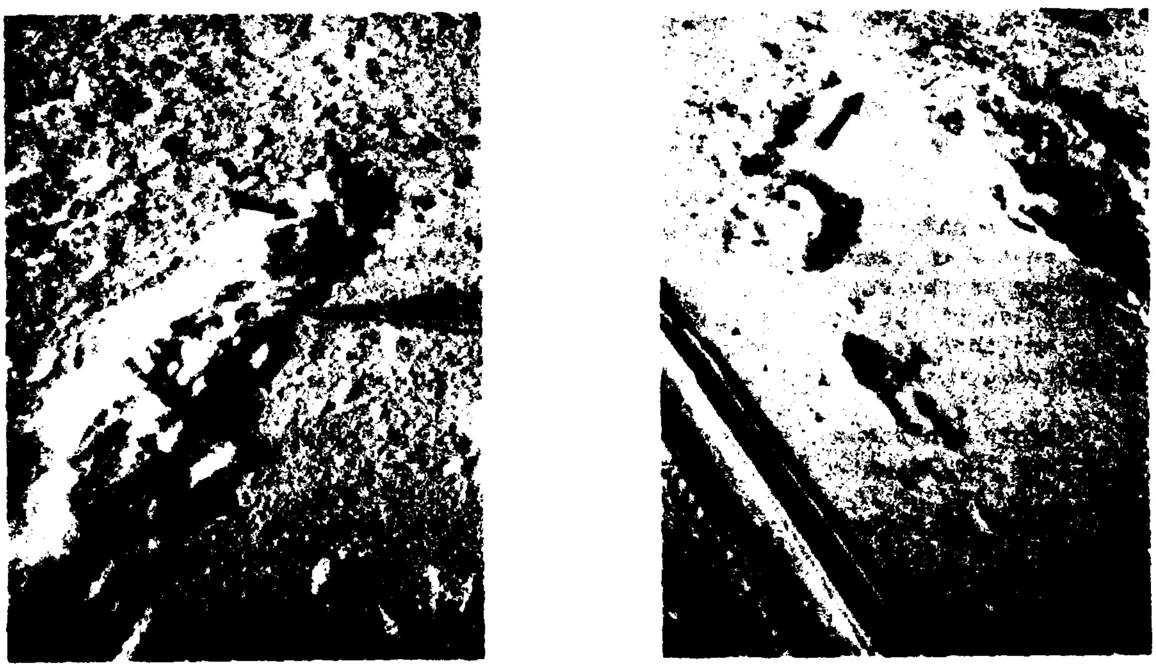


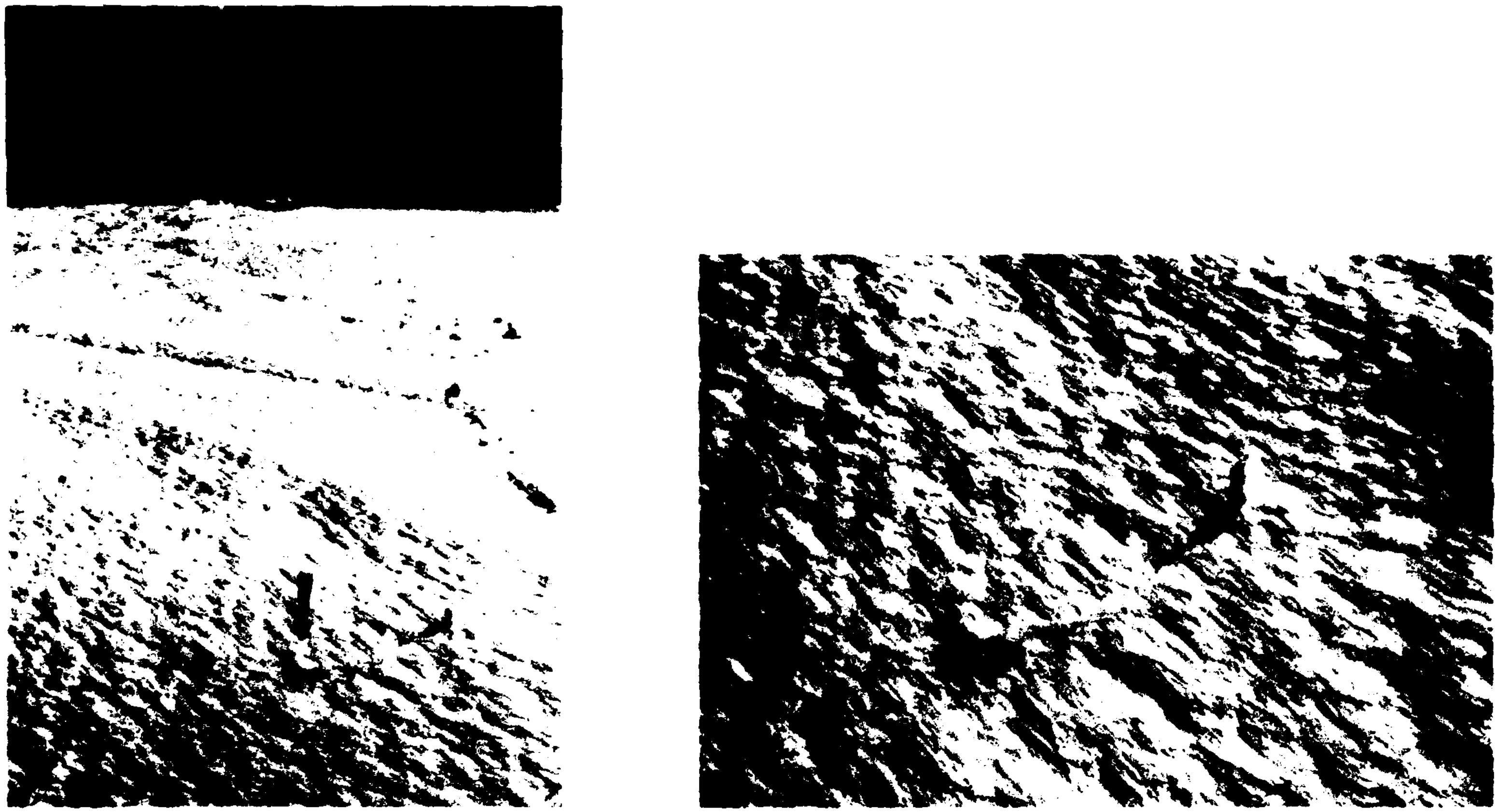
Figure A5. Typical inert rounds retrieved on the 20-mm strafing range. Note the soft aluminum nose section that was exposed when paint was abraded from the projectile on the left.



a. Nonbroaching

b. Broaching

Figure A6. Initial impact patterns typical for 20-mm (a) nonbroaching and (b) broaching rounds.



a. b.

Figure A7. 20-mm inert round that broached and came to rest about 50 m down range from target. Note the curve of trajectory due to spin and reversal of the projectile just before it stopped.

a.

b.

c.

Figure A8. 20-mm inert round that broached and came to rest about 150m from about 30° to rt. of target (arrow in a). Note reversal of projectile before it rolled sideways the last 2 meters.

The resumption of the scheduled testing prevented further observations. The conclusion was that a snow cover will influence the terminal ballistics of both bombs and bullets. It can not be estimated what the results would be with live ammunition, but the observations here are worth reviewing if such a study is to be attempted.